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Evaluation Parameters for 360-Degree Situational Awareness Systems on Military Ground Vehicles

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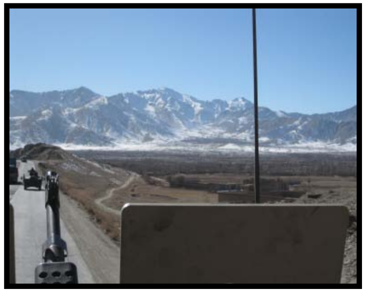
Introduction

- 360-Degree Situational Awareness (360 SA) Systems Offer Great Capabilities to Warfighters in the Field
  - Increase Combat Effectiveness
  - Increase Warfighter Safety



Introduction

- To Transition 360 SA Systems to the Field, Operationally Relevant Requirements Must Be Developed

- 360 SA Requirements Must Be Based Upon a Relevant Set of Evaluation Parameters in the Following Areas:
  - Vehicle-Mounted Visual Sensors
  - Data Transmission Systems
  - In-Vehicle Displays
  - Intelligent Cuing Technologies
  - Human Factors Considerations

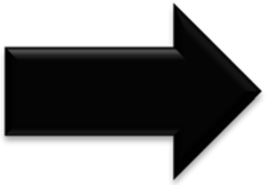
Previous Work

- In 2008, CERDEC NVESD Worked with Industry to Build 360 (H) x 90 (V) Distributed Aperture System (DAS)
  - 33 Sensors: De-Warped, Stitched, and Fused in Real-Time
  - Color Day, Image Intensified, and Uncooled Infrared Imagers
- Integrated Onto the M2 Bradley Fighting Vehicle
  - Increased Soldier SA When Compared to Baseline Vehicle
  - Important Limitations:
    - Required Substantial Computational Capabilities
    - Cost-Prohibitive in Production

Previous Work

- IMOPAT ATO[1] Established to Develop Cost-Effective 360 SA System for Ground Combat Vehicle (GCV)
  - **Objective**: Limit Per-Unit Cost to Ease Transition into the Field
  - Included Capabilities:
    - High-Resolution Sensors and Displays
    - Advanced Warfighter-Machine Interfaces (WMI)
    - Automated Control and Threat Cuing Algorithms
    - Occupant Workload Management Systems

Experimental Platforms

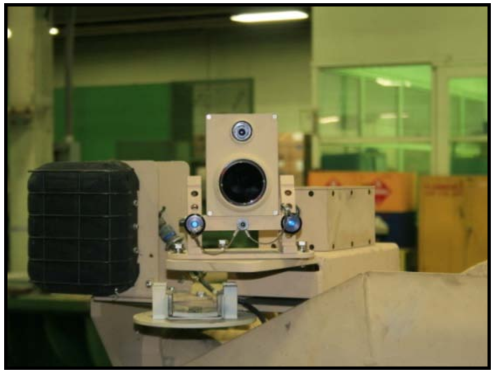


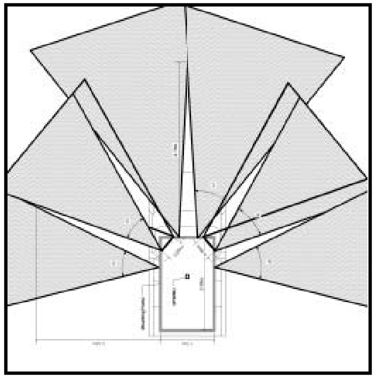
Fielded Systems

[1] Improved Mobility and Operational Performance through Autonomous Technologies Army Technology Objective

Vehicle-Mounted Visual Sensors

- Visual Sensors Are Fundamental Components of 360 SA
  - *Detect*, *Recognize*, and *Identify* Threats from Safe Distance
  - Used to Augment Other Sensors Upon Vehicle
- A Single Sensor Cannot Tend to Sometimes-Conflicting Requirements of Complete 360 SA System
  - Thus, Vehicle-Mounted 360 SA Systems Are *Designed in Layers* to Account for Conflicting Requirements





Vehicle-Mounted Visual Sensors

- **Detection Layer**
  - Set of Fixed, Wide FOV Sensors That Offer Simultaneous 360-Degree Coverage of Surrounding Environment
- **Interrogation Layer**
  - Set of High-Resolution, Narrow FOV Sensors That Interrogate Threats Discovered in Detection Layer
- **Broad-Area SA Layer**
  - Video Communication with Unmanned Aerial Systems (UASs), Unmanned Ground Vehicles (UGVs), and Other Assets

Vehicle-Mounted Visual Sensors [Evaluation Parameters]

- ***Simultaneous Field of View***: The FOV That a 360 SA System Concurrently Obtains Across All Sensors Upon Vehicle

- ***Sensor Field of View***: FOV of Single Sensor in 360 SA System
  - Fundamental Trade-Off Between *Sensor FOV* and *Range Performance*

- ***Range Performance***: The Maximum Distance of a Target from Imager At Which an Observer Can Conduct Discrimination Task

- ***Ground Intercept***: The Nearest Intercept of a Sensor's Cone of Vision with the Ground

Data Transmission Systems

- Data Transmission Systems Transfer Information from One Component of 360 SA System to Another
  - Example: *Visual Sensor* to *In-Vehicle Display*

- Analog Systems Provide Acceptable *Reliability*, *Ease of Integration*, and *Latency*
  - Drawbacks: Limited *Resolution* & *Video Processing* Capabilities

Data Transmission Systems

- 360 SA Systems Aim to Adopt Digital Video Architectures
  - New Limitations: Greater *Bandwidth* and *Latency* Constraints

- Despite Limitations, Digital Video Offers Opportunities to Provide Advanced Capabilities:
  - Discriminate Threats via Intelligent Cuing Technologies
  - Identify Potential Improvised Explosive Devices
  - Record Visual Sensor Information for Future Analysis
  - Share Video Information with Other Battlefield Resources

Data Transmission Systems [Evaluation Parameters]

ROBOTIC SYSTEMS

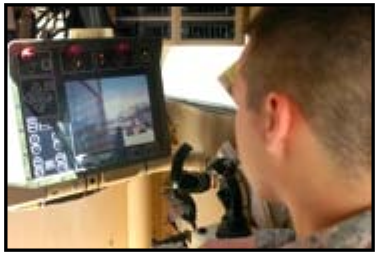
Camera Type	Resolution	Frame Rate	Bits / Sec
LWIR	640x480	30	73,728,000
LWIR	1024x768	30	330,301,440
Color VGA	640x480	30	221,184,000
NTSC (Square)	640x480	30	221,184,000
NTSC (Rect.)	720x480	30	248,832,000
Color XGA	1024x768	30	566,231,040
720p HDTV	1280x720	30	663,552,000
Color Video	1280x960	30	884,736,000
Color SXGA	1280x1024	30	943,718,400
Color UXGA	1600x1200	30	1,382,400,000
1080p24	1920x1080	24	1,194,393,600
1080p HDTV	1920x1080	30	1,492,992,000

- ***Bandwidth***: The Amount of Information That Can Flow Between Components of a Given 360 SA System
- ***Latency***: Delay from the Moment Event Is Captured by a Sensor to the Moment It Appears on an In-Vehicle Display
  - Should Be Below *80 Milliseconds*

In-Vehicle Displays

- In-Vehicle Displays Are Vital Components of 360 SA
  - Display Warfighter-Machine Interface to Vehicle Occupants
  - Provide Interface to 360 SA Video Sensor Imagery
  - Provide Interface to Vehicle Diagnostic and Management Functions
- Display Resolution Must Match or Exceed Sensor Resolutions
  - Advanced Sensors Cannot Be Fully Utilized Without Adequate Displays





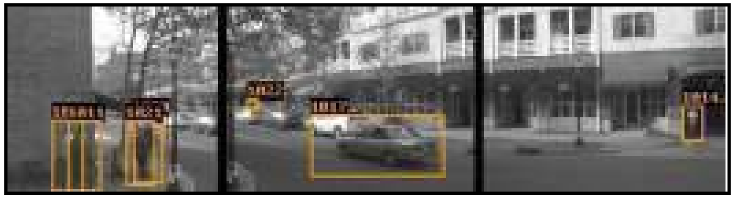
In-Vehicle Displays [Evaluation Parameters]

ROBOTIC SYSTEMS

- ***Screen Size***: The Physical Dimensions of the In-Vehicle Display
  - Constrains the Capabilities of the Warfighter-Machine Interface
- ***Screen Resolution***: The Number of Pixels within the Vertical and Horizontal Components of the In-Vehicle Display
  - Must At Least Match the Resolution of Vehicle-Mounted Sensors
- ***Brightness and Contrast***: Must Be Chosen to Maximize Warfighter Ability to Visualize Sensor Imagery
  - Brightness: The Maximum Luminance of In-Vehicle Display
  - Contrast: The Ratio of Brightest to Darkest Color That Display May Produce

Intelligent Cuing Technologies

- Intelligent Cuing Technologies Aim to Minimize Cognitive Load Upon Warfighters:
  - Draw Warfighters' Attention to Potential Enemy Combatants, Improvised Explosive Devices, and Other Battlefield Threats
  - Classify the *Threat Level* of Detected Objects
  - Identify Road Edges or Traversable Off-Road Terrains



Intelligent Cuing Technologies

- Intelligent Technologies Are Often Unreliable
  - Inherently Based Upon Statistical Methods
  - Rely Upon Noisy Sensors in Unstructured Environments
- Intelligent Systems Require High Computational Capabilities
  - Directly Impacts *Latency Requirements*

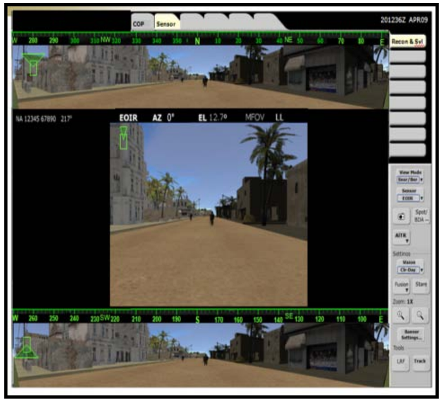
Intelligent Cuing Technologies [Evaluation Parameters]

ROBOTIC SYSTEMS

- ***Probability of Correct Detection***: The Probability That a System Correctly Detects the Event for Which It Was Designed
  - *Perfect Detection Unrealistic*
  - Yet, Cannot Be So Low As to Render System **Ineffective**
- ***False Alarm Rate***: The Rate at Which a System Misrepresents a Non-Event as an Event for Which It Was Designed
  - *Perfect False Alarm Rate Unrealistic*
  - Yet, Cannot Be So High As to Render System **Unreliable**
- ***Computational Load***: The Computational Capabilities Required to Drive Intelligent Cuing Algorithm
  - Must Minimize Burden on *Support Systems* and Maintain *Latency Requirements*

Human Factors Considerations

- Cognitive Load Must Be Minimized through Effective WMIs
  - WMIs Provide Access to 360 SA Capabilities
  - Must Be *Simple to Use*
- Human Factors Research Has Brought About Development of Standard Metrics to Assess WMI Effectiveness
  - Helps to Ascertain the *Ease* and *Quickness* with Which the Warfighter Interacts with 360 SA System



Human Factors Considerations [Evaluation Parameters]

ROBOTIC SYSTEMS

- ***Probability of Correct Identification***: Represent the User's Ability to Correctly Identify a Target in a Given Environment
  - Constraints: Environmental Stressors, Visual Display Characteristics, Decision Aids, and User Training Modules

- ***Glance Time***: The Time a User Needs to Visually Sample a Scene through the WMI

- ***Movement Time***: The Time a User Needs to Manipulate a Control Within the WMI

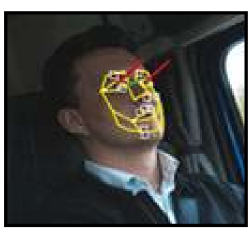
- ***Reaction Time***: The Time Elapsed Between the Onset of Warfighter Stimulus and His Response

IMOPAT ATO

360/90 Day/Night
Near-Field Sensor Coverage

Advanced Crew Stations

Integration Platform



Occupant Monitoring

Goals

Develop *Indirect Vision* and *Drive by Wire* Systems that Provide Electro-Optic Indirect Vision Based **Local Situational Awareness** and **Mobility Capabilities** At or Above the Performance Levels of Direct Vision Mechanical Drive Systems and to Enhance High-Definition Cognition Technologies to Dynamically Manage Workload to Increase Operational Performance on Future Platforms.

Objective

TARDEC-Led IMOPAT ATO Contains CERDEC-NVESD, ARL-HRED, and NSRDEC as Joint Partners to Mature *Visual Sensor Suites*, *Human Integration*, and *Assisted Mobility Technologies* in Three Phases of Evolution:

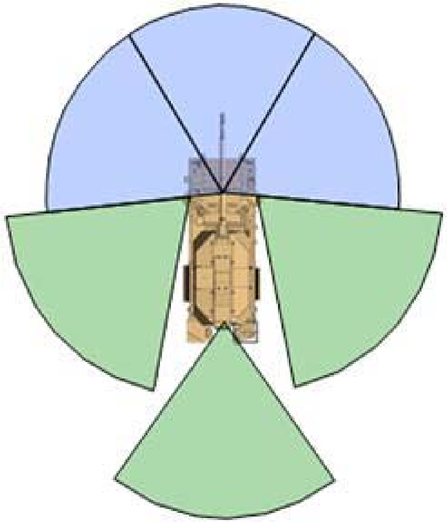
- Baseline: Establish Initial *Indirect Vision Driving (IVD)* and *360-Degree Local Situational Awareness (LSA)* Capabilities.
- Enhanced: Increase IVD and LSA Capabilities.
- Advanced: Integrated State-of-the-Art IVD and LSA System that Provides “Secure Mobility Capability”.

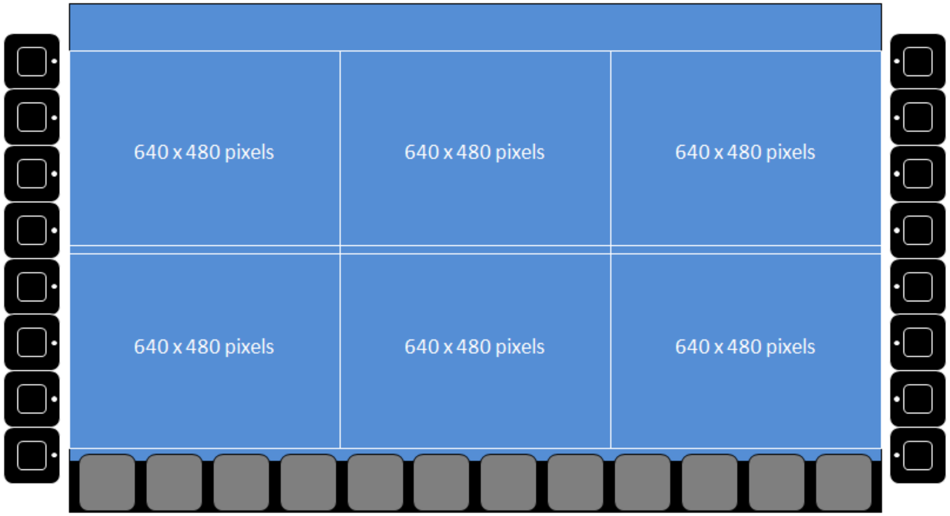
IMOPAT ATO

ROBOTIC SYSTEMS

- 360 SA Systems Upon Other Vehicle Platforms Have Similar *Designs, Characteristics*, and *Requirements*
  - Yet Generally, Development Efforts Are **Largely Independent**

- Years of Trial and Experimentation Have Promoted *Standard 360 SA Design Practices*
  - Increased Collaboration Between Technical and Military Operational Experts Now Required to Develop Standard Requirements





Questions?

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